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Study of Emission Parameters of Ir(III)-Ba Film System

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Abstract

Electrophysical properties of Ir(III)-Ba metal-film system have been studied by thermoionic emission (TE), surface ionization (SI) and thermal desorption spectroscopy (TDS) methods. It has been found that the optimum coverage of barium atoms on iridium (III) face is $\theta_{\text{opt}} = 0.70 \pm 0.05$. The dependence of fractional charge of Richardson constant of Ir(III)-Ba metal-film system on coverage θ of the Ba atoms in the interval $0 \leq \theta \leq 1$ has been experimentally obtained. The dependence of work function of Ir(III)-Ba metal-film system on coverage θ of Ba atoms has been obtained.

1. Introduction

A number of works [1-3] have been devoted to the study of Ir(III)-Ba metal-film system. In [1-2] it has been studied the adsorption and condensation of Barium atoms on iridium face (III) and the dependence of Ir(III)-Ba metal-film system work function on Ba atoms deposition time has been obtained from the Richardson formula assuming that the Richardson constant is not changed. It was shown in [3] that in going from iridium face (III) to the film system of iridium face with barium monolayer, the Richardson constant is approximantely reduced to one-fourth of its original value of that is why it is impossible to neglect the change of Richardson constant in studying the dependence of work function of Ir(III)-Ba film system on coverage of Ba atoms.

The aim of this work is to study the dependence of work function and functional charge of Richardson constant on coverage θ of baruum stoms on the iridium face (III) and to determine the optimum coverage θ_{opt} of Ba atoms on Ir(III).

2. Experimental Methods

The present experiments were made in a sector type high-vacuum magnetic mass spectrometric installation with 90° of ions trajectory deviation angle. The pressure of

residual gases in the instrument was $P \sim 10^{-10}$ Torr. The irridium face (III) was obtained. In accordance with the known methods [4]. A piece of 50×0.03 mm iriduim tape was placed in front of the entrace slit of the mass spectrometer on its focus. The tape was heated by passing an elecric the current throughit. The temperature of the tape was measured by means of an optical pyrometer, but in a non-pyrometric area where it was possible to measure the thermoionic emission current, using the Richardson formulae, as in [5]. The lower temperature was estimated by extrapolation of the temperature dependence on filament current-to room temperature. The mass analyzer had two sources of ions: 1) volume inonization; and 2) surface ionization. A schematic diagram of source of ions is shown in Figure 1. Flow of atoms and molecules was directed to the surface of specimen (I) from evaporation pats (2) and (3). Flow of particles from evaporator 2 could be intercepted by electromagnetic gate (4) controlled from out side the instrument. The ions from surface ionization formed on the specimen were drawn into the magnetic field through the accelerating slit of electrode and, according to m/q, were recorded in the mass-analyzer receiver. The collector (6) with suppressor grid (5) was used to measure the current of thermoionic emission in the specimen and, in some cases, to measure the current of surface ionization. The second source (7) of mass-analyzer with ionization of electrons of the desorbed particles from the specimen was the source of Nira type [6]. To remove thermal desorption spectum of Ba atoms from the surface of iridium tape, its temperature was linearly raised at a rate of 100 K/s, and the Ba^+ ions current was recoorded. To exclude thermal-desorption of Ba^+ positive ions, a small negative potential was applied on the iridium tape.

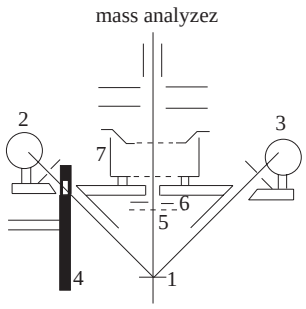

Figure 1. Ionic source of mass-analyzer

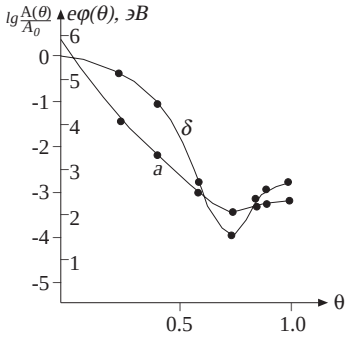

Figure 2. The dependence of the work function $e\varphi$ (a) and the ratio of the Richardson constants $\ell g A(\Theta)/A_0$ (b) on the coverage θ of Ba atoms on Ir(III) face

3. Experimental Results

3.1. Determination of Optimum Coverage of Ba Atoms on Ir face (III)

Depending on thermoionic emission current from the iridium face (III) on the deposition time of Ba atoms, the maximum, which corresponds to the minimum work function, of Ir(III)-Ba system was observed. As it is currently accepted, the coverage corresponding to the minimum work function is called the optimum (θ_{opt}. To determine $\theta_{\text{opt}} = N_{\text{opt}}/N_m$. a comparison of concentration of Ba atoms on Ir(III) corresponding to the optimum coverage N_{opt} and monolayer N_m was made. This romaparison was made by examinins the peak areas of TDS ions of Ba^+ corres ponding to the optimum coverage and monolayer of atoms on iridium face (III) in the following way. First, at temperatures which show no evident desorption of Ba atoms (as demonstrated by experiments with $T_a \leq 1100$ K, that Ba atoms with Ir(III) are not practically desorbed, due to the ionic emission current from Ir(III) intercepting the flow of Ba atoms a coating of Ba atoms on Ir(III) corresponding to the optimum coverage was produced. Then the flow of Ba atoms was intercepted and a TDS of Ba^+ ions was recorded. To obtain a monolayer of Ba atoms on an iridium face (III) not having clusters and other formations, we employed the intercalation phenomenon with Ba atoms deposited following a monolayer of graphite on Ir(III) [7]. For this purpose, at first, from decomposition of C_6H_6 molecules were decomposed to obtaine the graphite monolayer with deposition monitored by measuring the change of work function and dissociation of CaCl [8] on the iridium face heated up to $T = 1700$ K and exposed to benzene vapour under pressure of $P_{C_6H_6} \sim 2.10^{-6}$ Torr. After at temperature $T = 700$ K the Ir(III)-C system was exwposed to radiation of Ba atoms with the density of $\nu_{B\alpha} \approx 5.10^{12}$ cm^{-2}.g^{-1} for a definite time. After intercepting the flow of Ba atoms the TDS of Ba^+ ions were recorded from the Ir(III)-C system. Then this procedure was repeated for exposition times $t > t_1$. Analysis of the TDS of BBa^+ ions has shown that, due to increase of exposure time, the quantity of intercalated Ba atoms (Ba atoms under the graphite monolayer) increased to a definite value after which it does not change with increasing exposure time. It was assumed by us that a monolayer of BBa atoms had formed on the iridium face (III) under the graphite monolayer. Optimum coverage of Barium atoms on the iridium face was found by comparing the TDS Ba^+ peaks ions corresponding to optimum coverage and monolayer data; and the value $\theta_{\text{opt}}= 0.70\pm0.05$ was obtained.

3.2. Dependence of Work Function and Relative Richardson Constant on Coverage of Barium Atoms on Iridium Face (III)

Determination of θ_{opt} enables to build dependence of work function of Ir(III)-Ba film system on coverage of Ba atoms. Let a flow of Barium atoms with density ν fall on the surface of an iridium face (III). Then at temperatures $T \leq T_a$, for which iridium has no desorption of Ba atoms, the followlwing relationships can be written: $N = \nu t$, $N_{\text{opt}} = \nu t_{\text{opt}}$ and $N_m = \nu t_{\text{opt}}$, on where N, N_{opt} and N_m are the number of Barium

atoms on 1 cm^2 area of iridium face (III) for moments of time corresponding to optional coverage (θ), optimum coverage ($\theta = \theta_{opt}$) and monolayer ($\theta_m = 1$), respectively. From these relationships, it is possible to find θ and N as functions of deposition time t:

$$\theta = \frac{t}{t_{opt}} \cdot \theta_{opt} \tag{1}$$

$$\theta = \frac{t}{t_{opt}} \cdot N_{opt} \tag{2}$$

For determination of N from Eqn.(2), it is necessary to define $N\theta_{opt}$. It is known that on face (IOIO) Re [9], on face (100) W from textured tapes [10,11] and on face (112) W [12], a plane concentration of Barrium atoms corresponding to the minimum of work function has a value $N\theta_{opt} \simeq 4.10^{14}$ cm^{-2}. The same result was obtained in [2] by means of graduating the flow of Ba atoms in a comparison of currents of surface ionization of Ba atoms on tungsten faces (100) and on faces (111) of iridium textured tape. These results show that an optimum concentration of Ba atoms is basically determined by their interaction, but the structure of a metallic base is of no particular inportance. That's why $N_{opt} = 4.10^{14}$ cm^{-2} was accepted in this work. We used the value N_{opt} to determine the density of flow of Barium atoms $\nu = N_{opt}/t_{opt}$ and to define N according to formula (2). The work function of metal-film system from Richardson formula can be found from the expressions

$$e\varphi(t) = e\varphi_0 - \kappa T_a \ell n \left[\frac{I(t)}{I_0} \cdot \frac{A_0}{A(t)}\right], \tag{3}$$

where $e\varphi_0$ and $e\varphi(t)$ are work functions; I_0 and $I(t)$ are thermoionic emission current: A_0 and $A(t)$ are Richardson constants at the temperature of Ta adsorption for homogeneous metal surface and metal-film system correspondingly in the moment of deposition time t

As a rule, in determination of $e\varphi(t)$ according to this method, by changing the Richardson constant, it is disregarded and considered that $A_0/A(\theta) = 1$. However, as it was shown in [3], in going from Ir face (III) to its Ir (III)-Ba film system with coverage of Ba atoms, $\theta = 1$, the Richardson constant is approximately decreases by four orders of magnetude. The same takes place form many other metal-film system [13]. That's why, for construction of $e\varphi(t)$ from t according to formula (3), it is impossible to neglect the change of Richardson constant.

In this work the dependence of $e\varphi(\theta)$ on θ for the Ir(III)-Ba system was obtained by the following method. At temperatures $T \leq T_\alpha$ a coating of Ba atoms with coverage θ at an interval of $0 < \theta < 1$ was created on an Ir face (III) and for each value of θ determined by formula (1), and the temperature dependence of TE current was removed. The absence of abnormal Schottky effect has shown that Ir face (III)-Ba metal-film system is homogeneous as per work function for all covarges. That is why, the work function of Ir face (III)-Ba system corresponding to various values of coverage of Ba atoms on iridium face (III) was can be found from the plots $\ell g(I/T^2) = f(5040/T)$. The dependence of

$e\varphi(\theta)$ on θ for metal-film systems of Ir(III)-Ba is shown in Figure 2 (a). As it is seen from the plot, due to increase of $\theta, e\varphi(\theta)$ decreases and becomes minimum when $\theta = \theta_{\text{opt}}$, but then poor growth is observed. The plot $\ell g(A/A(\theta)) = f(\theta)$ is given in the same figure. It should be noted that determination of the ratio $A_0/A(\theta)$ was calculated from Richardson formula. As it is seen in Figure 2(b), for Ir face (III)-Ba metal-film system due to increase of θ, the ratio $A_0/A(\theta)$ is monotoically changed with the change of work function $e\varphi_p(\theta)$.

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